THE METEOROLOGICAL MAGAZINE

M.O. 422

AIR MINISTRY : METEOROLOGICAL OFFICE

Vol. 74 February 1939 No. 877

FOREWORD

This issue of the *Meteorological Magazine* introduces a new volume, and the occasion has been taken to make certain changes both in its appearance and in its contents. Thanks to the co-operation of H.M. Stationery Office, the magazine is now printed in bolder type on a better quality of paper, whilst the stiffer cover carries a simplified decorative design. At the same time the original size of page has been retained so that bound volumes will be uniform with those of previous years. The nature and arrangement of the contents have also been modified. Certain features which were deemed to be of little general interest have been omitted, whilst it is proposed to include regularly authoritative articles upon a variety of meteorological subjects and problems. These articles will treat their subjects as simply as possible, and all highly technical matter will be excluded. The introduction of a " Notes and News " column will provide information upon minor events which are of general interest.

It is hoped that these changes, many of which have been suggested by Mr. E. G. Bilham, will render the *Meteorological Magazine* more acceptable to its present readers and will also increase its appeal to a wider range of readers who, whilst not participating actively in meteorological work, are nevertheless interested in its progress and problems.

N. K. JOHNSON.

THE FILM AS A METEOROLOGICAL INSTRUMENT

By J. S. Farquharson, M.A.

Sir Napier Shaw(1)* was the first, or among the first of meteorologists to perceive the possibilities of the cinematograph camera as an aid to the observation and analysis of visible atmospheric phenomena. On September 23rd, 1911, at Sheringham, in front of an advancing depression, photographs were taken with a cinematograph camera, under his supervision, of cirrus, cirro-cumulus and alto-cumulus. The photographs were taken at intervals of 5 or 10 seconds over a period of about three-quarters of an hour and were used to illustrate the view that, under falling pressure, cloud (in this case cirrus) cools to a less extent than the air of its environment and instability develops in consequence at the upper surface of the cloud. Between the time of this early adoption of the cinematograph camera for meteorological purposes and later work of a similar type, there appears to be a large gap. Sir Napier Shaw himself, however, made at least one other meteorological film. This, like the earlier film, showed how far in advance of his time Sir Napier was, in that the technique of the animated diagram was used to illustrate the development and advance of a depression.

From about the year 1925 interest in the cinematograph camera as an instrument for the increase of meteorological knowledge appears to have revived, particularly on the continent. Since that year an increasing number of films on clouds have been made using speeded up photography. By the choice of a suitable ratio of camera speed to ultimate projection speed, the movements of a changing cloud can be shewn speeded up to any desired extent. This technique is employed in all of the modern films of clouds. Beautiful and striking effects are so achieved, cloud masses being shewn in a constantly changing state of development or dissipation, like masses of steam. Devaux, in 1928, was able to deduce from films made in this way that the intervals between the

* The numbers refer to the list of references at the end.

rolls of strato-cumulus clouds over the Pic du Midi were areas of descending currents. In the same year, Masanao Abe(2), based an analysis of the nature of the turbulence near the summit of Mount Fuji in Japan, on the information conveyed by a similar type of film, while in a later, more ambitious study(3), involving similar technique, he arrived at conclusions as to the velocity and direction of air flow, which were supported by experiments on a model of the mountain placed in a wind tunnel. Included among French meteorologists who have used the technique of accelerated cinematography in the analysis of cloud developments are P. Idrac(4) and Kampé de Feriet(5). The films discussed by the latter shed considerable light on the influence of topography on the formation, maintenance and dissipation of clouds.

In this country attention was first directed to the renewed interest in the cinematography of clouds at the British Association meeting of 1933, at which were shewn some films of clouds made by Prof. Linke of Frankfurt, using the technique indicated above. M. G. Bennett, describing these films in Vol. 68 of this Magazine stated that the photographs were taken at intervals of from 3 to 6 seconds and projected at the normal projection speed of 16 pictures per second. Late in the same year, or early in 1934, photographs of similar type were taken for the first time, so far as is known, in this country, by Mr. F. A. Goodliffe of Messrs. Science Films Ltd., an amateur meteorologist and professional cinematographer. He has a collection of beautiful films of developing clouds, made in this way, and brief excerpts from his collection are incorporated in the two films entitled " Fog " and " Ice Formation " which were made for the Air Ministry. These were shewn at the meeting of the Royal Meteorological Society on December 15th, 1938. Some idea of the results achieved may be obtained from Figs. 1 to 4. These are reproductions of individual pictures or " frames " taken from one of Mr. Goodliffe's films. The photographs were taken at Leatherhead in the afternoon of a day last summer in the evening of

which heavy thunderstorms developed in the neighbourhood of London. The camera pointed north-westwards. Surface winds were south-westerly, but a change of wind occurred aloft, the fragments of cloud visible at the top edge of the photographs being remains of a cumulonimbus or large cumulus south-east of the camera. Exposures were made every two seconds but the time interval in the photographs reproduced is ten minutes between Figs. 1 and 2 and five minutes each between Figs. 2 to 4, Fig. 1 representing conditions at 5 p.m. (summer-time). The obvious change in the field of view from Fig. 2 to Fig. 3 is due to a change of lens and to a slight adjustment of the orientation of the camera. The " boiling-up " of the central cumulus cloud and the general turbulence is well shewn in these photographs, together with the ultimate development of the anvil. The great complexity of the turbulent developments is more plainly apparent in the cinematograph pictures projected on a screen. The tendency for the large cumulus to be eclipsed by other clouds, which is apparent in these photographs, is noteworthy because it exemplifies one of the greatest difficulties in making cinematographic studies of individual cloud masses. Another difficulty is that the rate of movement of the cloud under observation may be such as to carry it beyond the effective range of the camera before the photographic study of its life history is complete. These difficulties, however, could be overcome if unrestricted means were available so that batteries of cinematograph cameras might be used instead of individual cameras.

The most ambitious study of clouds by means of what may be termed " accelerated cinematography " is that made by Prof. Müggе in the Black Forest and western Germany in 1936 and 1937. He made a series of films and analysed the air movements disclosed by them in a number of papers whose titles give some indication of the clouds photographed: " Fine Weather Cumulus ", " Cloud Formation in Non-Ascending Air Currents ", " Stable Sliding Processes ", " Castellatus Processes " and " Spreading and Drooping ". The papers are not

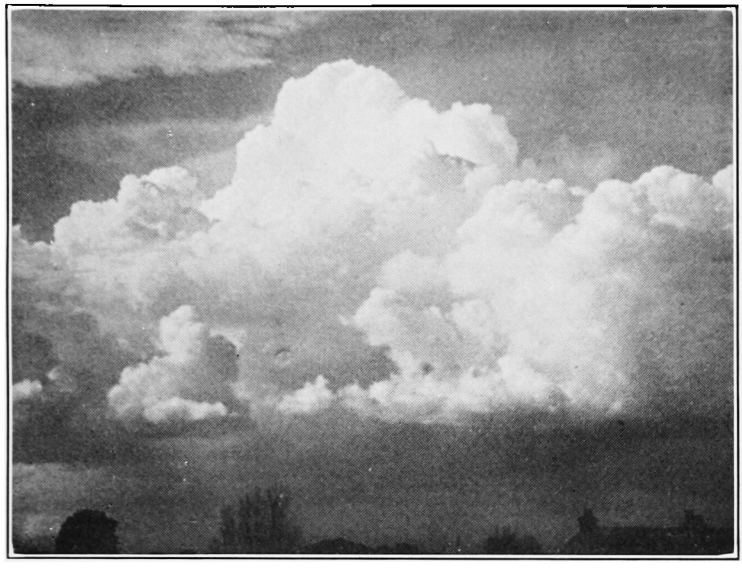


FIG. 1

FIG. 2

(*Photographs from film by F. A. Goodliffe, reproduced by permission of Messrs. Science Films Ltd.*)

Facing page 5]

FIG. 3

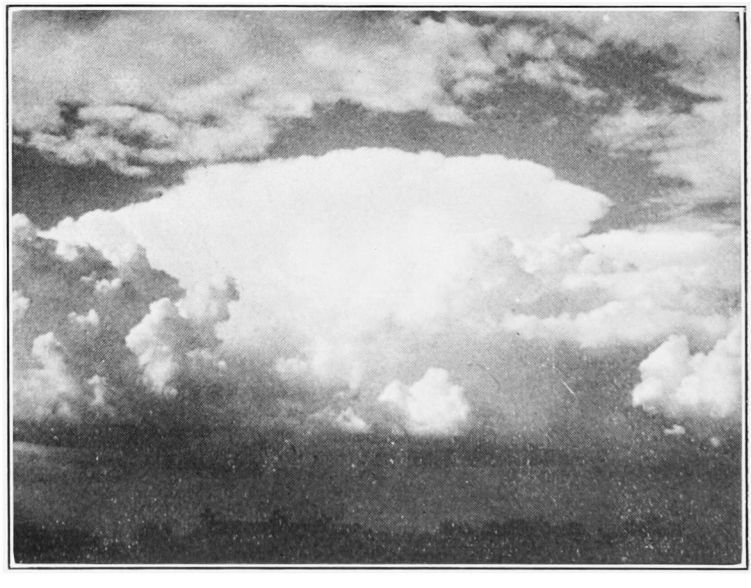


FIG. 4

(*Photographs from film by F. A. Goodliffe, reproduced by permission of Messrs. Science Films Ltd.*)

published but are written as commentaries on the films, copies of which were bought by the Meteorological Office. Prof. Mügge appears to have been in the fortunate position of being able to take some of his photographs from the summit of one or more of the peaks in the Black Forest region so that portions of his films are free from the first difficulty referred to above. A description of one of these films is given by Prof. Linke(6) in the *Quarterly Journal of the Royal Meteorological Society*.

The criticism was made of Prof. Mügge's films, based on the projected pictures, that the highest photographic technique and the best photographic material had not been employed in making them. Though the limit of the possibilities of the cinematograph camera, as used so far, as a means of research into the air movements in and near clouds appears to have been reached, nevertheless it is thought that further progress along these lines might be made if the highest available photographic technique were used in collaboration with expert meteorological knowledge. More might be learned if, during the period covered by the photographs, simultaneous observations of temperature and humidity in and near the cloud under observation were made. No technical difficulty is foreseen in the synchronisation of cinematograph photographs with self-recording instruments. The difficulty of interpretation of some microbarograph records might disappear if a synchronised film of cloud developments were available during the period covered by the records. Numerous fields for the employment of the cinematograph camera in meteorological research suggest themselves. Prof. Brunt(7) of the Imperial College, London, has already employed it to secure pictures supporting his theory as to the movements of air in cloud sheets of strato cumulus type. As mentioned above, Sir Napier Shaw made a film, of a rudimentary character, some years ago of a weather map using the technique of the animated diagram. It is a moot point whether the meteorologist has nothing to learn from a film of this character, and it would be interesting to have such a film made covering the sequence of events on the weather map, complete with

fronts of, say, north-west Europe, using technique which has progressed considerably since the time Sir Napier's film was made.

In this country complete meteorological films have been made only for educational purposes, apart from those made by Sir Napier Shaw. Since the processes involved in meteorological phenomena are frequently complicated it is not immediately apparent that the film is a particularly suitable teaching medium. That it is so, however, is due to the fact that the ideas it is desired to convey must first be simplified so as to be readily assimilable in the form of pictures. Further, to drive home a point the producer of the educational film can perform " experiments " which it would be physically impossible to perform in the laboratory though the physical basis of the " experiment " were perfectly sound. The educational film has recently been adopted by the Air Ministry as an aid to the training of young pilots in the fundamentals of meteorology with which they should be familiar. A great advantage of such films is that there is no limit to the number of times the points in a lesson may be gone over since the film may be projected as often as necessary.

REFERENCES.

(*This list is not exhaustive.*)

(1) Dines, W. H. " The Free Atmosphere in the Region of the British Isles ", *London, Geophys. Mem.* 2, 1912, with a preface by W. N. Shaw, p. 18.

(2) Abe, Masanao. " Cinematograph Studies of Rotary Motion of a Cloud Mass near Mt. Fuji ", *Tokyo, Geophys. Mag.* I, 1928, pp. 211–228.

(3) Abe, Masanao. " Local Air Current of Mt. Fuji, as observed by the motion of cloud by the aid of the Cinematograph ", *Tokyo, Geophys. Mag.* III, 1930, pp. 45–58.

(4) Idrac, P. " Sur l'étude des mouvements internes des masses nuageuses par la cinématographie accelerée ", *Paris, C.R. Acad. Sci.* 197, 1933, pp. 1341–1342.

(5) Kampé, de Feriet, J. " Atmospherische Stromungen; Wolkenstudien nach Kinoaufnachmen im Hochgebirge (Jungfrau und Matterhorn) ", *Met. Z. Braunschweig,* 53, 1936, pp. 277–280.

(6) Linke, F. " An Account of Prof. Mügge's Film Clouds in Motion; The Thunderstorm ", *London, Quart. J.R. Met. Soc.,* LXIII, 1937, pp. 73–75.

(7) Brunt, D. " Natural and Artificial Clouds " (Symons Memorial Lecture, March, 1937), *London, Quart. J.R. Met. Soc.,* 63, 1937, pp. 277–288.

THE EVOLUTION OF THE EARTH'S ATMOSPHERE

BY THE ASTRONOMER ROYAL,
DR. H. SPENCER JONES, F.R.S.

From the Fourteenth Annual Norman Lockyer Lecture, delivered under the auspices of the British Association, December 6th, 1938.

From theoretical considerations it is possible to decide whether or not any planet may be expected to possess an atmosphere. The natural tendency of an atmosphere is to diffuse away into space. The molecules of the atmosphere are flying about in all directions at high speeds, continually colliding with one another and rebounding. In the upper layers of the atmosphere, the preponderant tendency is for them to be pushed outwards. They are prevented from escaping only by the gravitational pull of the planet.

In order to overcome this pull and to fly away into space, any particle, whether large or small, must acquire a velocity greater than a certain minimum value, determined by the mass and radius of the planet. If the radial component of the outward velocity is greater than this minimum value, the particle will escape from the planet, provided its motion is not impeded by collision with another particle.

In a simple gas, at a uniform temperature, the velocities of the molecules are distributed according to a law, discovered by Maxwell, which he first announced at the meeting of the British Association in 1859. The mean velocity of the molecules increases with the temperature, being proportional to $\sqrt{T}$; the number of fast-moving molecules with velocities much in excess of the mean velocity falls off very rapidly with increase of velocity. In a mixture of gases, the average energy of each type of molecule is the same; the lighter the molecules the faster they move in the mean.

There are definite proportions of molecules with speeds of 10, 20 or 100 times the mean speed, so that there must be a progressive loss of fast-moving molecules from the upper layers of the atmosphere of any planet. The

rate at which this loss takes place depends upon the relative magnitudes of the velocity of escape and of the mean velocity of the molecules. The rates of escape were calculated by Jeans. He found that if the velocity of escape is four times the mean molecular velocity, the atmosphere would be practically completely lost in fifty thousand years; if the velocity of escape is four and a half times the mean molecular velocity, the atmosphere would be lost in thirty million years; whilst if the velocity of escape is five times the mean molecular velocity, twenty-five thousand million years would be required for the loss to be almost complete. The age of the planets is believed to be of the order of three or four thousand million years, so that if the velocity of escape is as great as five times the mean molecular velocity of hydrogen the atmosphere will be practically immune from loss.

Coming to the Earth, the escape velocity is 11·2 km./sec., which is almost exactly six times the mean molecular velocity of hydrogen at 0° C. Hence the atmosphere of the Earth should be immune from loss of hydrogen and all other gases.

At the present time the amounts of hydrogen and of helium in the Earth's atmosphere are very small. The spectrum of the aurora does not contain the lines of helium, an indication that the high regions of the atmosphere cannot contain very much helium. The total helium content of the atmosphere has been estimated to be about five parts in a million. The supply is being gradually replenished by the weathering of the igneous rocks of the earth's crust, which contain uranium and thorium and also, consequently, helium. Yet the atmosphere does not now contain more than a fraction of the amount of helium that it has gained in geological times in the process of the formation of sedimentary rocks as a result of the weathering of the igneous rocks. We may therefore say that there is direct observational evidence that helium is being lost from the atmosphere at the present time. It is believed that there may be a state of equilibrium between the rate of supply and the rate of loss.

Even if the Earth had remained hot, in the early stages of its existence, for a sufficient time for the hydrogen and helium then present in its atmosphere to escape entirely, it still remains to explain how helium continues to be lost when, according to the theoretical results, which are based on the accepted principles of the kinetic theory of gases, it should be immune from loss. There is one process by which the escape of helium can be brought about. It is well known that the night sky is faintly luminous. In addition to the light from the stars there is a faint luminescence from the upper atmosphere, whose brightness seems to vary with the sun-spot cycle, being greater at sun-spot maximum than at sun-spot minimum. Lord Rayleigh has termed this the non-polar aurora. In the spectrum of the night sky the characteristic green auroral line, as well as the two red lines, are always present. These lines are emitted by oxygen atoms that are in what the physicists term a metastable state. An atom, when excited or loaded up with energy, usually unloads its energy, with the emission of radiation, within a short interval of time of the order of one hundred-millionth of a second. But a metastable state is characterised by the peculiarity that the atoms in that state have a very slight tendency to unload their energy. They may remain for an average time of a second or longer in that state before emitting their energy in the form of radiation. There is a high probability that before this occurs the atom will have collided with another atom. When a collision of a metastable oxygen atom with another atom occurs, the energy of the oxygen atom will be unloaded and converted into kinetic energy. The two atoms will rebound with a greatly increased speed. By such a collision an atom of helium could acquire a speed of more than 12 km./sec., which is greater than the velocity of escape from the Earth. Hydrogen atoms would acquire a still higher speed, but heavier atoms, such as those of nitrogen or oxygen, would not by this process acquire sufficient speed to escape. They would receive an equal amount of energy but, being heavier, they would not move so fast. The

loss of hydrogen and helium from the atmosphere of the Earth is thus made possible by the fact that free oxygen is present in the atmosphere.

It appears probable that the primitive Earth must have remained hot sufficiently long for most of its initial atmosphere to have been lost. It was pointed out by Russell and Menzel that in the stars and the nebulæ neon is as abundant as argon, whereas in the Earth's atmosphere argon is five hundred times more abundant than neon. Nitrogen is far less abundant on the Earth than in the stars; it is ten thousand times more abundant in the Sun than on the Earth. These large differences in relative terrestrial and solar abundance demand explanation, because in general the relative abundance of elements on the Earth is in close agreement with their relative abundance in the Sun and other stars. These facts can be accounted for on the supposition that the rate of loss of atmosphere was very rapid when the Earth was hot. When the cooling had proceeded sufficiently far for the escape of the atmosphere to cease, neon had been depleted to a much greater extent than the heavier argon. If this supposition is correct, much of the original oxygen, nitrogen, and water-vapour and all the original helium and free hydrogen must have been lost. As the molten Earth cooled, great quantities of water-vapour, carbon dioxide and other gases must have been evolved from the solidifying magma; these, with the residual gases from the initial atmosphere, formed the new atmosphere which, as the Earth was then relatively cool, could not escape.

It has been recognized for more than a century that the presence of free oxygen in the atmosphere of the Earth, which we are apt to take for granted without a thought, needs explanation. Oxygen is an element that is chemically active and processes are in continual operation that are depleting the store of oxygen in the atmosphere. One of the principal sources of depletion arises from the weathering of the igneous rocks to form sedimentary deposits—sand, clay and mud. The iron contained in the igneous rocks is not completely oxidised.

The greyish hue of these rocks results from the iron being present mainly in the form of ferrous oxide. During the process of weathering, much of the ferrous oxide is oxidised into ferric oxide, which gives the red or brown tints to the weathered deposits. The amount of oxygen that is withdrawn from the atmosphere by this process is very considerable and it has been estimated that during geological times the amount of oxygen thus depleted from the atmosphere is about twice the quantity now present. It is clear that some process must be in operation which replenishes the oxygen in the atmosphere. The vegetation over the Earth's surface provides the means for this replenishment. The green plant absorbs carbon dioxide from the air and uses energy from sunlight to decompose it, the energy-transformer being the green colouring matter, called chlorophyll, contained in the plant cells. The carbon is used to build up the complex organic substances found in living plants, the oxygen being returned to the atmosphere as a by-product.

The supply of carbon dioxide is in turn renewed by the decay of vegetable matter and other organic materials. During the decay of such matter, oxygen is absorbed and carbon dioxide is liberated. This carbon dioxide is again available for building up new plant cells. Whenever organic matter is buried, as in coal measures and oil deposits, so that it cannot become oxidised and decay, there is a net gain of oxygen to the atmosphere. It seems probable that the present abundance of oxygen in the atmosphere has been provided in this way and that if the coal, oil and other organic deposits could be unburied and completely burned, the whole of the oxygen in the atmosphere would be used up.

FROST AND SNOW IN DECEMBER AND JANUARY

By C. K. M. Douglas, B.A.

On the evening of December 17th, 1938, cold east winds of Siberian origin reached south-east England and ushered in the coldest succession of days and the longest period of continuous frost since February, 1929, when there was a still colder spell which originated in a rather similar manner. Temperature remained below freezing point over a large area from December 18th to 21st inclusive, and in Kent for two more days. At Lympne the maximum temperature was 22° F. on 20th and 24° F. on 21st. The proximity of the Continent made south Kent distinctly the coldest area, but on the Continent itself temperature was much lower, the 13h. temperature on 20th being from 10° to 12° F. over Holland, Belgium and north-east France. By 19th the cold air had extended over the whole of the British Isles, the maximum temperature at Valentia being 35° F. from 19th to 21st. The cold air was about 20,000 feet deep on 20th at both Mildenhall and Aldergrove.

Pressure was high in Siberia throughout the month, but the actual anticyclonic centre which proved the decisive feature developed on the north coast of Siberia, in the neighbourhood of Dickson, 73° N. 80°E., where pressure rose to 1056 mb. on December 12th. By the 15th the centre had moved 1,000 miles to S.W. and intensified to 1064 mb. at about 62° N. 48° E., i.e., westward of the Urals. An old anticyclone over south Russia was absorbed, and winds over European Russia became easterly on 14th, three days before the cold air reached England. In February, 1929, the anticyclone also moved a considerable distance westward.

The distribution of snowfall was very different in the 1929 and 1938 cold spells. In the earlier period the snowfall was very heavy in the SW, but in the SE there was none, except locally on the east coast. In the recent case the south-eastern area had most snow, and experienced its heaviest fall since December, 1927. In the lower parts of London the 1927 fall was wet, but the

1938 fall was dry, and lay deeper than in the earlier year. Perhaps someone with long experience of the London streets and parks can say when the Metropolis last had a similar fall.

On December 19th and 20th there were snowfalls of instability type which even in the south-east exceeded an inch locally, in spite of the fact that the air had only crossed a short expanse of sea. On 19th the Mildenhall

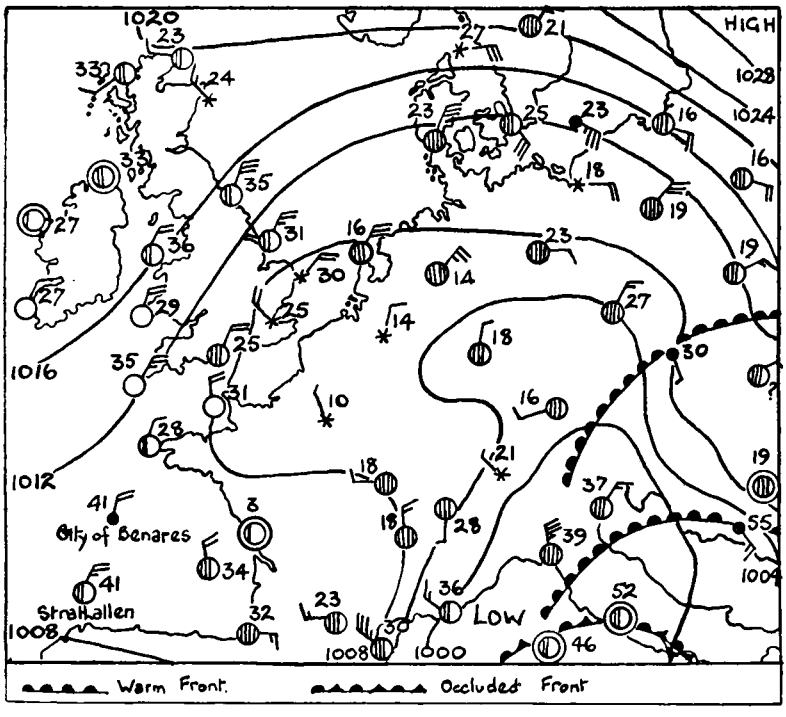


FIG. 1.—WEDNESDAY, DECEMBER 21ST, 1938, 7H.

observations showed that instability only extended to 5,000 feet, and that the clouds were only 2,000 feet thick. Locally they were probably 3,000 feet thick, but even so the amount of precipitation was surprisingly large, and could only have occurred at low temperatures, when ice crystals form readily.

On the 21st about 6 inches of snow fell over a large area in the south-east, and on 22nd there were further falls, so that aggregates were up to 9 inches at many places. The area most affected was east of a line from

Yorkshire to Dorset. From the meteorological point of view, the chief interest of this snowfall was the excellent example it provided of the development of precipitation at an upper warm front. The sea level chart for 7h. on 21st is shown on Fig. 1 with the nearest surface warm front over south-east Germany. Surface

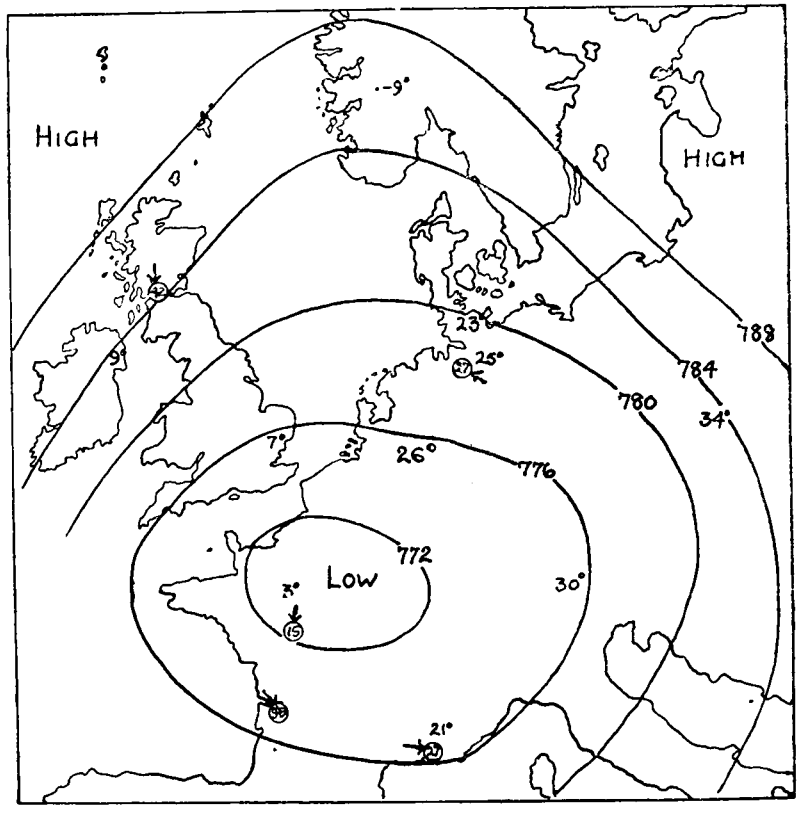


FIG. 2.—WEDNESDAY, DECEMBER 31ST, 1938, 7H.

Isobaric chart at 2 kilometre level, also showing temperature in °F at certain places and wind in kilometres per hour.

temperatures had risen at some places in advance of this front, but the precipitation area was over south-east England and adjacent parts of the Continent, mostly to westward of the region of lowest temperatures up to the 2,700 feet level. There was no appreciable precipitation over Germany during the 36 hours ending 7h. on 21st, but snow commenced in Belgium and north-east France during the night of 20th–21st and soon spread to

England; the belt of precipitation increased in size and intensity and moved slowly westward. Fig. 2 shows the synoptic chart at the level of 2 kilometres, and it can be seen that the temperature over Cologne was 19° F warmer than at Mildenhall, showing the upper warm front in the right position for the precipitation area. (The temperature of 31° over Munich is from the 13h. observations; there was evidently an error of transmission in the 6h readings). The coldest air was over France. There was an unusually large inversion over Germany, with an angle of slope from Breslau to Cologne of less than 1 in 2,000. From Cologne to Mildenhall the angle of slope of the surface of discontinuity seems to have been about 1 in 200, but there was no inversion over Mildenhall, only a thick transitional layer, so that accurate computation is impossible. Considering the negligible angle of slope over Germany, there seems to have been a genuine development of an upper warm front. The warm air had come from the Mediterranean, circulating round the upper depression over France, and since its relative humidity was high it must have passed just east of the Alps.

The arrival of warmer air aloft reacted on the surface temperature, especially where the air had a long sea track, and on 22nd there was a thaw except in the extreme SE, but over a large area in the Midlands and in eastern districts south of the Wash the thaw was very slight and temporary, and the snow did not melt appreciably till the evening of December 26th, when the severe spell ended.

The snowfalls of January were of a commoner type, occurring on the north sides of depressions moving directly over the British Isles. Six such depressions crossed the country, of which four gave widespread snow, and finally a depression moved up the English Channel and caused heavy snowfall in the south. Some of the depressions moved further south than could have been anticipated from sea level observations, notably that of January 21st, which gave no snow owing to the general mildness. In no case was the general temperature

(best shown at coast stations) really low, and the snow lay chiefly on the high ground, though some low areas also had snow. In most northern districts the period from January 1st to 6th was more severe than the

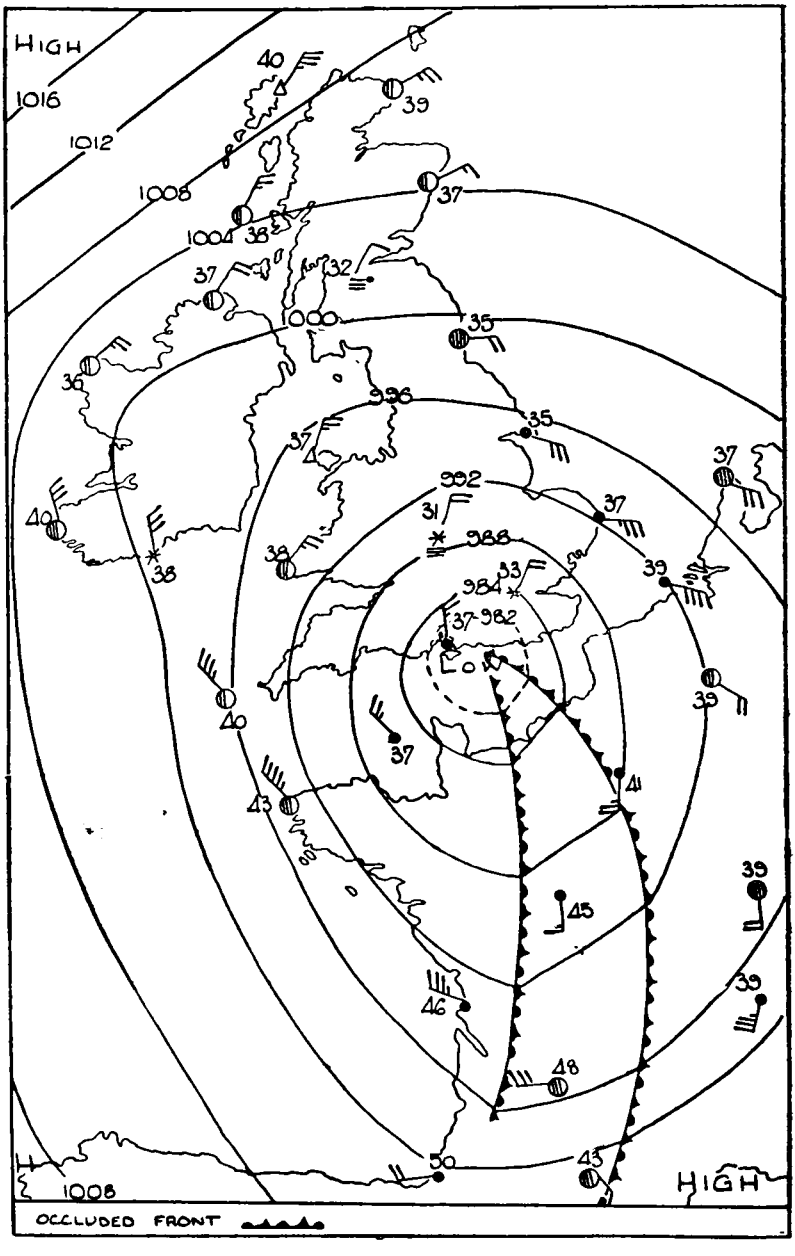


FIG. 3. WEDNESDAY, JANUARY 25TH, 1939, 18H.

December spell, and there was renewed wintry weather from 10th to 14th. There were a number of " radiation nights ", and the screen minima at Dalwhinnie from 4th to 6th were 1° F., 8° F. and 3° F. respectively. Other notable minima were 14° F. at Aldergrove on 5th and 12° F. at Manchester (Barton) and 14° F. at Sealand on 6th. On 5th fog prevented temperature at Manchester from rising above 23° F.

On 25th (see Fig. 3) a heavy snowfall occurred in the south, and round London the interference with traffic was as great as during the December snowfall. The amount of precipitation was greater, but on low ground most of the snow melted as it fell. The snow was of the clinging type and great damage was done to overhead wires. A railway accident occurred near Hatfield on 26th in consequence of the breakdown of telephone lines and signals. A train was snowed up in Wales. On 24th temperature exceeded 40° F. generally. There was a touch of frost in the night, but the continuance of snow inland all day in spite of a fresh east wind, when east coast temperatures were 35° F. to 37° F. with rain, can only be attributed to the intensity of the precipitation. (It may be noted that the December 1927 storm only gave sleet near the East Anglian Coast). Had the precipitation been moderate, temperature would have been appreciably higher and very much less snow would have lain. The heaviest precipitation so far reported was in the form of rain in the south and south-east coasts, but Kew Observatory had snow and sleet and recorded 1·18 in. rainfall in the 30 hours ended 7 hours on 26th. Twenty miles further north, at Welwyn Garden City, the rainfall was 1·54 in. for the 30 hours ending 9h. on 26th, and 9 inches of wet snow were found to contain 1·51 in. rainfall, the remaining 0·03 in. having soaked away. It is difficult to explain the amount of precipitation. The depression was well occluded but deepened from 995 to 980 mb. at the centre between 7h. and 18h. on 25th, as it moved up the Channel, apparently owing to a secondary warm sector between the main occlusion and the back-bent occlusion. The Mildenhall upper air

temperature observations at 7h. on 25th showed marked stability from 750 to 500 mb. (7,600 to 17,600 ft.), a state of affairs typical of continuous precipitation. The height of the base of the stable layer was of course determined by the distance of the front, at that time 200 miles off.

The heavy rainfall, following a long wet spell, gave severe flooding, notably round Ipswich, and melting snow also caused floods in the Thames Valley and elsewhere. The depression moved away southwards and filled up, and a spell of east winds set in, but in the absence of cold air on the Continent the temperature remained above freezing point, except high up, and the snow melted away, though above 300 feet there was still a little at the end of the month. There was severe drifting on the hills, especially on the higher hills in south-west England and Wales, where much snow must have remained till February.

OFFICIAL PUBLICATION

An investigation of the lapse rate of temperature in the lowest hundred metres of the atmosphere. By N. K. Johnson, M.Sc., and G. S. P. Heywood, M.A., D.Sc., *Geophysical Memoirs,* No. 77, 1938. (M.O. 419e).

In an earlier *Geophysical Memoir* (No. 46) an account was given of the investigation at Porton of the lapse rate of temperature in the lowest seventeen metres of the atmosphere. The present paper describes the instrumental equipment used at Leafield for the extended investigation, and gives a detailed analysis of the five-years' records, with various tables and diagrams. Stress is laid on the steps taken to determine the characteristics and possible sources of error in the more important of the instruments, while the paper concludes with a more detailed discussion of some of the observational results.

LETTERS TO THE EDITOR

On "Gradient Winds"

Dr. Harold Jeffreys, in 1922, observed that pressure gradient is important in all types of air motion and based his well-known " classification of winds " on the relative importance of the other factors. He did not employ the term " gradient wind ", and one may justly ask: by what peculiar virtue can this name be applied to any special type of motion when gradient is a controlling factor in all winds? It is, I suggest, an objectionable term for anything—it is doubly objectionable when it is used differently by different writers as is the case at present.

In most foreign publications, and pretty widely also in England (not excepting a recent official publication) gradient wind is used as a synonym for geostrophic wind. In the Meteorological Glossary and in other English text-books, the term is used for the geostrophic wind " corrected " by allowing for curvature. The former usage is understandable, for to obtain the geostrophic wind the meteorologist in practice simply measures the pressure gradient—he regards geostrophic wind as merely a function of gradient and calls it naturally enough the gradient wind. But to use " gradient " to describe something which depends on curvature is, at best, illogical. The confusion is not unimportant for, at present, if one comes across " gradient wind " in any work, one simply does not know what is meant, unless the context gives a clue. One school of thought should, I think, withdraw publicly and perhaps the *Meteorological Magazine* will provide a medium for discussion. I give my first vote for dropping " gradient wind " altogether and my second choice to using it as an equivalent for " geostrophic wind ". This is not only in deference to what I believe will be a majority vote but because I never quite know what is the precise definition of the other more complicated " gradient wind ". In the case of uniform, stationary, circular motion, it is plain

enough, but if I were asked what is this gradient wind on any ordinary weather map I should hesitate. Does it depend on the curvature of the isobars or on the unknown curvature of the path of the air? Does it include the isallobaric term or is this an additional factor? Does it, in general, form a legitimate second approximation to the true wind? My impression is that it is a theoretical wind, based on the assumption that the fields of pressure and of motion are stationary and that the air is moving with constant speed along the isobars, so that tangential acceleration is ignored. As such, it is a highly hypothetical wind of very limited practical application and has no call whatever to monopolize the " gradient ".

In so far as there is a wind defined by the stationary isobars, it may properly be called the " isobaric wind " to which the " isallobaric wind " might with certain approximations be taken as simply additive. If we wish to deal with the mathematically consoling case of uniform circular motion, let us use a very special term—the geo-cyclostrophic wind—which will be sufficient to keep it from being misused on a real weather map.

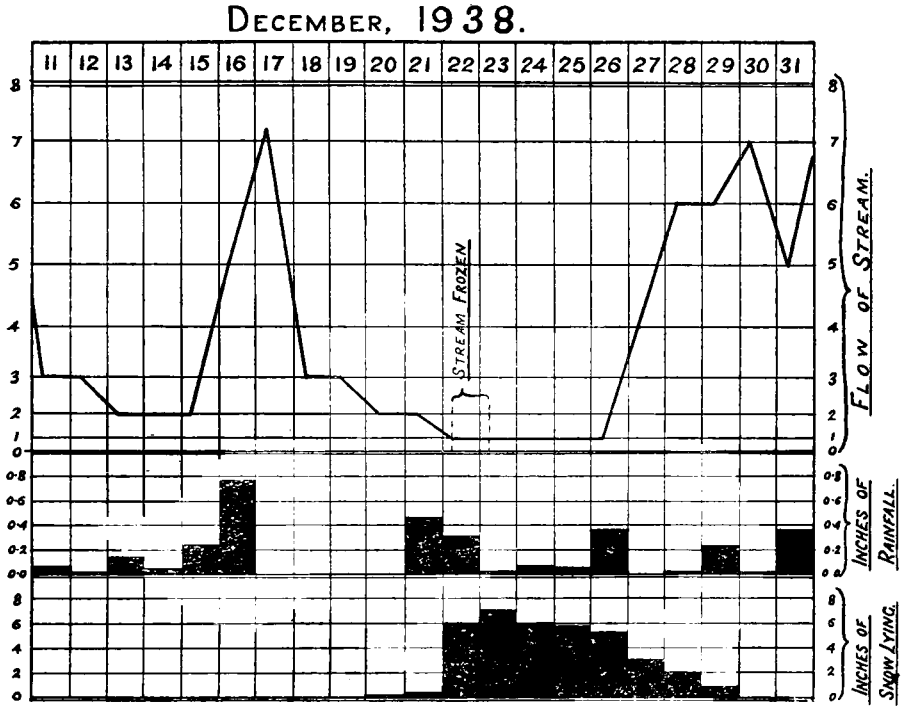
R. C. SUTCLIFFE.

Thorney Island, January 9th, 1939.

Snowfall and Stream Flow

The cold spell of December last, produced an excellent demonstration of delayed stream flow at Cuffley Brook, Herts. Observations of the flow of this stream, and details of the catchment area have been described in this Magazine, 1937 pp. 180–2, and the scale of flow shown in the accompanying figure is in accordance with that previously described viz. 0 = bed dry to 8 = more than 24 inches over the concrete invert of a bridge. As will be seen in this figure, the rainfall of 0·96 in. during December 15th and 16th, 1938, gave a usual rise in flow from 2·0 to 7·2 on the morning of the 17th. The flow fell abruptly during the next 24 hours to 3·0 and then more gradually to 1·0 by the morning of the 23rd. Considerable snow fell during the eight days 18th to 25th, lying

7 inches in depth at 7h. on the 23rd, equivalent in aggregate to 0·86 in. rainfall, of which 0·75 in. fell during the 21st and 22nd. In spite of this heavy snowfall (the heaviest in this district since December 1927) the stream continued to flow at 1·0, i.e., less than 1 inch in depth, except during the 22nd and 23rd, when in fact it ceased to flow owing to its being completely frozen. The


DECEMBER, 1938.
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
STREAM FROZEN
FLOW OF STREAM.
INCHES OF RAINFALL.
INCHES OF SNOW LYING.

SNOWFALL AND STREAM FLOW AT CUFFLEY BROOK

stream flow did not increase in volume until the combined effects of the thaw and rainfall of 0·34 in. on the 26th raised the flow to 4·0 at 7h. 45m. on the 27th. No precipitation was observed on the 27th, but the thawing snow further increased the stream flow to 6·0 on the morning of the 28th, thereafter the flow resumed its normal volume in relation to rainfall. Thus it will be seen that the snowfall delayed the stream flow for approximately five days. The thaw itself took four days

completely to remove the snow cover, possibly this was due to the hard wind-crust, about $1\frac{1}{2}$ inches in thickness, having formed on the snow surface during the 24th and 25th.

DONALD L. CHAMPION.

Meteorological Station, 7, Robinson Avenue, Goff's Oak, Herts. January 24th, 1939.

A Lunar Halo

On looking up at the sky on the morning of January 8th, at 24h. 50m., I observed a lunar halo, in the form of a pale white ring, of 22°. A sheet of " cirro nebula " covered the sky, and there were also a few small pieces of fracto-stratus cloud moving rapidly across it.

Ten minutes later, that is, at 1h., I saw that the sky was now practically covered with the fracto-stratus cloud, on which was thrown a corona by the moon. Where there were gaps in the layer, the halo could still be seen on the " nebula " cloud.

Finally, on looking out at 1h. 5m., I observed that the sky was completely covered with " alto-stratus opacus " cloud, on which there was no longer either halo or corona.

KENNETH R. PATRICK.

" San Mateo ", Castlemaine Avenue, Ewell, Epsom, Surrey. January 8th, 1939.

NOTES AND NEWS

" Windy Tuesday " February 18th, 1662.

There will be little difference of opinion that the greatest English storm of which any record remains was that of November 26th, 1703. A storm of the first magnitude, however, occurred on Tuesday, February 18th, 1662, and like that of 1703 the main brunt was confined to the southern half of the country and the Midlands. The gale was not exceptional in Yorkshire, the north and Scotland.

Many accounts of this storm by eye-witnesses survive and we may mention those of Samuel Pepys, Evelyn, Rugge and Dr. Robert Plot amongst others. An early

printed account appeared a few days after the event in the journal *Kingdom's Intelligencer* as follows:—This morning about four of the clock, February 18, began a most violent storm of rain mixt with lightning, which lasted about two hours, after which followed such an impetuous tempest of wind that I think the like was never known in these parts. It continued till almost noon. There was scarce any safety within doors or without. There is not a church nor house in this city but hath received some considerable loss. The highways are so full of fallen trees that travellers can hardly pass.

A tract was speedily published with the title " A Full and Certain Account of the last Great Wind and Storms . . . . " There is also a full account in the remarkable tract " Mirabilis Annus Secundus ", published late in 1662. Daniel Defoe quoted this account in full in the early chapters of his work on the greater storm of 1703.

There were many casualties to persons in the southern half of England in this storm of 1662, including several in London, notably the Stamford attorney, Mr. Luke Blith, who was killed while walking in Piccadilly by the collapse of a Riding-house. Another notable victim was Lady Sanderson who was killed in her bed at Covent Garden by the fall of the house. The damage done to churches was very great. Windows were blown in at Tewkesbury, and the cathedrals at Worcester and Hereford were damaged. Finchinfield church, Essex, suffered the loss of its spire which fell into the nave. The spire of the Tower church at Ipswich was similarly blown off and fell, upper end foremost, into the Church. Audley End House was very badly damaged and barns, windmills, smaller property, and trees innumerable were destroyed. In the New Pond in St. James' Park, Westminster, the water was blown out of the pond and the fish were mostly left stranded on the banks. The date of this notable storm came to be known as Windy Tuesday.

Samuel Pepys describes how the streets " were everywhere full of brick-batts and tyles flung down by the

extraordinary winde last night " and proceeds to give an account of the damage in various places including his own property at Brampton. Evelyn describes the damage done to his house at Sayes and his London residence. So violent was the storm at Hereford that the Scottish chronicler John Nicoll was moved to give an account of it in his Diary of Public Transactions. Another Scottish diarist, Alexander Brodie, notes on this occasion that there was " veri tempestuous wether ". The learned Dr. Robert Plot braved the elements at Oxford in order to see a very uncommon spectacle. He says of the wind:—" . . . it was yet so violent that it laved water out of the River Cherwell, and cast it quite over the Bridge at Magdalen College, above the surface of the river near 20 foot high; which passage, with advantage of holding by the College wall, I had then the curiosity to go to see my self, which otherwise perhaps, I should have as hardly credited as some other persons may now do."

Commenting on this storm, Dr. Plot quotes the opinion of an " able-Seaman of Bristol " to the effect that " this wind was the fag-end of a Hurricane which began in New England about three hours before ".

C. E. BRITTON.

Low barometric reading.

A depression a few hundred miles off west Ireland on January 15th, 1939, attained an abnormal depth. A ship at 13h. recorded 944 mb., and from two ships' readings near the centre at 18h. it is evident that the pressure at the centre was still at least as low as 944 mb. The depression filled up remarkably rapidly between 16th and 17th, pressure at the centre rising about 30 mb. in 24 hours.

Royal Meteorological Society.

The Annual General Meeting of the Society was held on January 18th. Dr. B. A. Keen, who was re-elected President, was in the chair. He delivered an address

on " What happens to the rain?" and a brief summary of this follows:—

An annual rainfall of 30 inches means that 3,000 tons of water fall on an acre of land. In the course of the year this all disappears, by run-off, evaporation, transpiration through vegetation, and by downward percolation. The relative importance of these factors in British and overseas conditions were discussed. Many of the traditional beliefs among farmers and gardeners were based on a theory of water movement that was attractively simple to understand—but incorrect. It is only in recent years that the true picture of the movement of water in the soil has been built up. In consequence, some of the traditional practices need revision, while others now have a different explanation. The new work has also clarified some of the concepts used in hydrology.

Lieutenant-Commander F. W. Reichelderfer.

The appointment of Chief of the United States Weather Bureau, rendered vacant by the untimely death of Dr. W. R. Gregg in September 1938, remained unfilled until recently, when the President appointed Lieutenant-Commander F. W. Reichelderfer of the U.S. Navy as the new Chief. The selection of such a world-renowned aviator-meteorologist to fill this important appointment has succeeded in re-awakening public interest in the status and organization of the Weather Bureau, which is a part of the Department of Agriculture.

Commander Reichelderfer has been closely associated with this Department and with both the Army and the Navy and is held in high esteem by the whole aviation industry.

Mountain Meteorologists in Japan.

A meteorological observatory has been in operation on the summit of Mt. Fuji in Japan for the past seven years. The observatory is at a height of 12,388 feet and the observers have to face severe conditions in winter, severe blizzards being frequent—winds up to 90 miles an hour with temperatures in the neighbourhood

of 0° F. In order to keep the anemometer working during a blizzard, the observers have to remove icicles about once every five minutes. A minor trouble is that at the station pressure of about 630 mb. water boils at a temperature of only 87° C., so that special high-pressure kettles have to be used for cooking rice. Recently a party of medical officers has also been stationed at the observatory for " aero-medical " researches.

Radiation from the Sun and the Sky.

The importance of measurements of radiation from the sun and sky have long been recognized in Europe and North America. In India systematic investigations of solar radiation were commenced a few years ago, and are now proceeding actively; in a recent Memoir (Vol. 26, Part 8) of the Indian Meteorological Department, P. K. Raman, describes the work at the Agricultural Meteorological Observatory of Poona. The clear skies of November to May are especially favourable for measurements of solar radiation, the chief difficulty being dust from the roads. A Gorczynski Moll solarigraph gave records of the total solar and sky radiation, which are tabulated and discussed for the year 1935.

Meteorological Tables, Kew Observatory.

The table of daily readings at Kew Observatory (*see* page 29) has been reproduced each month since January 1934. The following elements are included: pressure and the strength and direction of the wind in the middle of the day (at 13h.); the extremes of temperature (night minimum and day maximum) and, for comparison with this maximum temperature, the relative humidity at 13h.; rainfall for the calendar day and the duration of bright sunshine. Short notes on the weather of the day are also set out, some of the letters of the Beaufort Weather code being used for brevity: The following Beaufort letters are the ones employed:—d, drizzle; f, fog; h, hail; i, intermittent; l, lightning; p, shower; q, squall; r, rain; s, snow; t, thunder; x, hoar frost. A capital letter is used to indicate intensity and a suffix o to indicate slight.

Sunshine, January 1939.

The distribution of bright sunshine for the month was as follows:—

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	61	+34	Chester ..	33	−20
Aberdeen ..	42	− 5	Ross-on-Wye	43	−12
Dublin ..	42	− 7	Falmouth ..	51	− 9
Birr Castle ..			Gorleston ..	44	−12
Valentia ..	42	− 2	Kew.. ..	45	+ 1

Kew temperature, mean, 42·1° F. : diff. from average, +0·8° F.

REVIEW

Science in Africa. By E. B. Worthington, $8\frac{1}{2} \times 5\frac{1}{2}$, pp. XVI + 746, *illus.*, Oxford Univ. Press, Humphrey Milford, London, 1938. Price 10*s.* 6*d.* net.

This impressive volume is one of the results of the comprehensive study of conditions in Africa made over a period of five years by Lord Hailey, and described at length in his great book "An African Survey". Dr. Worthington's companion volume consists of eighteen chapters, of which the first is entitled "Some Problems of Research", while the rest deal with different branches of science and were mostly written with the help of specialists. One chapter of 34 pages is devoted to meteorology and is by far the most comprehensive guide we have to the activities of the various governments in providing climatological data for agriculture and health services and upper air information and forecasts for aviation. It includes also a section on changes of climate, in which the suggestion is made that full understanding of climatic cycles in Africa may eventually lead to long-range weather forecasting. A discussion of "alleged progressive desiccation" reaches the conclusion that there is little evidence of an actual decrease of rainfall but that the destruction of forests may have altered the character of the rain and has certainly led to a more rapid run-off.

Even by itself this chapter shows that meteorology is of great importance in African economy, but it does

not stand alone. Almost every other science has need to call upon meteorology for enlightenment on its own especial problems. Much of the continent is on the borderline of aridity, and problems of water supply are urgent. Africa is mainly agricultural, and climate is now recognised as one of the most important factors determining the character of the soil as well as the possible range of crops. The question of the probable results of short-circuiting the sudd areas on the Nile involves meteorological considerations, especially the rate of evaporation. The debatable effects of forests on rainfall, soil moisture and the encroachment of deserts are referred to again and again. Climate even comes into the fish-curing industry!

The part played by meteorological conditions in the origin and development of locust outbreaks was recognised by the International Locust Conference in London in 1934 and a series of detailed maps of Africa are now being prepared in the Meteorological Office to study this connexion; meanwhile the interesting suggestion is made that locusts, like some other animals, have a definite periodicity of population which may be related to the sunspot cycle in meteorological elements. Finally there is the highly important but not yet fully understood problem of the effect of tropical sunshine, humidity and temperature on the human body and brain.

If any further evidence is required of the economic importance of meteorology, it is enough to compare the map of annual rainfall on p. 94 with that of density of population on p. 559. Apart from certain areas such as the irrigated Nile valley and the still undeveloped basin of the Congo, the two maps have sufficient resemblance to claim a fair degree of correlation—the Congo of course has too much of a good thing.

The book has a very full bibliography covering 77 pages and an exhaustive index, both of which add greatly to its value for reference. The price of half a guinea is low for a book of this calibre.

C. E. P. B.

Daily Readings at Kew Observatory, January 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir.	Force 13h.	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain	Sun	Remarks
	mb.			°F.	°F.	%	in.	hrs.	
1	991·5	SW	3	38	50	77	0·16	1·4	r_0–r 2h–9h.
2	993·0	W	3	40	40	90	0·02	0·0	pr_0– 2h & 17h.
3	1008·9	W	2	33	39	75	trace	2·2	is_0 5h–6h.
4	994·4	WSW	2	31	45	96	0·37	0·0	s_0–r 2h–12h, r_0 17h–
5	1012·8	NW	2	32	37	68	trace	5·1	pr_0 1h. [23h.
6	1022·0	WSW	2	25	36	85	trace	3·3	f 8h–19h, r_0 23h.
7	1015·4	SSW	3	31	52	99	0·36	0·0	r–r_0 3h–9h.
8	1016·4	SW	4	49	53	80	trace	0·2	ir_0 21h–22h.
9	1007·5	SSW	4	48	51	93	0·02	0·0	d_0–r_0 13h–14h.
10	1011·4	NNE	2	42	46	56	0·09	0·0	f 15h, r–r_0 17h–24h.
11	995·5	SW	4	41	47	71	0·08	0·5	r 3h–5h.
12	997·0	SW	3	35	41	71	—	5·5	
13	1002·4	SW	3	33	44	75	—	6·8	f–F 19h–24h.
14	1002·8	ESE	2	26	44	87	0·29	0·0	F 0h–11h, r–r_0 17h–24h.
15	993·9	SSW	5	43	54	74	0·35	2·2	p RQ 7h. r–r_0 18h–23h.
16	998·6	SSW	5	50	52	73	0·44	2·3	r_0–R 18h–21h.
17	988·4	SE	2	45	53	96	0·12	0·0	d 14h, r–r_0 17h–18h.
18	987·2	S	4	50	51	88	0·16	0·0	r–r_0 2h–4h. & 22h–24h.
19	1008·5	WNW	3	48	49	87	0·16	0·1	r 0h–2h & 22h–24h.
20	999·0	SSE	3	44	52	90	0·26	0·6	r 0h–1h & 16h–18h.
21	989·0	S	2	42	52	99	0·15	0·0	r 7h–10h, d_0 15h.
22	1002·6	S	3	47	49	84	0·05	0·4	pr_0 13h, 16h. & 23h.
23	998·0	NW	5	47	49	71	0·04	0·0	pr_0 9h, 13h & 17h.
24	1019·6	NW	3	39	43	62	—	7·0	f 20h–24h.
25	991·1	ENE	2	34	35	96	1·15	0·0	rs–S 4h–22h.
26	991·3	NNE	5	33	38	86	0·01	0·0	r_0 18h & 23h–24h.
27	1009·0	NNE	3	35	41	66	0·04	1·5	r_0 0h–3h & 7h–9h.
28	1014·2	NE	4	35	40	60	trace	3·3	pr_0 5h, 20h. & 23h.
29	1015·4	ENE	6	37	40	63	trace	0·0	pr_0 1h.
30	1017·5	ENE	5	38	39	69	—	0·0	
31	1018·5	ENE	4	36	39	72	—	3·0	
*	1003·3	—		39	45	79	4·32	1·5	* Means or Totals.

General Rainfall for January 1939

	Per cent.
England and Wales	220
Scotland	130
Ireland	128
British Isles	179

Rainfall: January 1939: England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond .	Camden Square.....	4·67	251	*War* .	Birminghm, Edgbaston	5·81	288
Sur .	Reigate, Wray Pk. Rd.	5·71	238	*Leics* .	Thornton Reservoir...	4·99	252
Kent .	Tenterden, Ashenden.	6·01	280	,, .	Belvoir Castle.....	4·06	229
,, .	Folkestone, I. Hospital	5·41	..	*Rut* .	Ridlington	5·26	284
,, .	Margate, Cliftonville..	4·37	263	*Lincs*.	Boston, Skirbeck.....	4·36	269
,, .	Eden'bdg.,Falconhurst	5·65	231	,, .	Cranwell Aerodrome..	3·75	218
Sus .	Compton, Compton Ho	6·69	210	,, .	Skegness, Marine Gdns	4·42	255
,, .	Patching Farm.....	5·90	227	,, .	Louth, Westgate.....	3·74	172
,, .	Eastbourne, Wil. Sq..	5·74	218	,, .	Brigg, Wrawby St....	3·72	..
Hants.	Ventnor, Roy.Nat.Hos.	5·72	223	*Notts* .	Mansfield, Carr Bank..	5·49	255
,, .	Southampton, East Pk	5·92	222	*Derby*.	Derby, The Arboretum	5·04	241
,, .	Ovington Rectory....	6·48	240	,, .	Buxton, Terrace Slopes	8·76	196
,, .	Sherborne St. John...	5·07	218	*Ches* .	Bidston Obsy.....	4·25	200
Herts .	Royston, Therfield Rec	4·79	277	*Lancs*.	Manchester, Whit. Pk.	4·64	185
Bucks.	Slough, Upton.....	4·81	259	,, .	Stonyhurst College...	5·33	125
Oxf .	Oxford, Radcliffe.....	4·45	246	,, .	Southport, Bedford Pk	4·34	170
N'hant	Wellingboro,Swanspool	5·27	285	,, .	Ulverston, Poaka Beck	5·12	119
,, .	Oundle	3·97	..	,, .	Lancaster, Greg Obsy.	4·10	117
Beds .	Woburn, Exptl. Farm.	4·26	249	,, .	Blackpool	3·87	142
Cam .	Cambridge, Bot. Gdns.	4·11	274	*Yorks*.	Wath-upon-Dearne	4·85	253
,, .	March	3·64	228	,, .	Wakefield,Clarence Pk.	5·31	276
Essex.	Chelmsford,CountyGdns	5·06	331	,, .	Oughtershaw Hall....	10·64	..
,, .	Lexden Hill House....	5·79	..	,, .	Wetherby, Ribston H.	4·39	213
Suff .	Haughley House.....	4·39	..	,, .	Hull, Pearson Park...	3·87	215
,, .	Rendlesham Hall.....	5·17	284	,, .	Holme-on-Spalding...	4·08	216
,, .	Lowestoft Sec. School.	4·78	286	,, .	Felixkirk, Mt. St. John	4·94	247
,, .	Bury St. Ed.,WestleyH	5·66	316	,, .	York, Museum	3·46	195
Norf..	Wells, Holkham Hall.	4·02	277	,, .	Pickering, Houndgate.	3·87	185
Wilts .	Porton, W.D. Exp'lStn	4·71	205	,, .	Scarborough.....	3·58	179
,, .	Bishops Cannings	5·19	224	,, .	Middlesbrough.....	3·93	246
Dor .	Weymouth, Westham.	5·67	233	,, .	Baldersdale, Hury Res.	6·59	203
,, .	Beaminster, East St ..	7·24	207	*Durh* .	Ushaw College.....	4·91	239
,, .	Shaftesbury	..	..	*Nor* .	Newcastle, Leazes Pk.	4·16	210
Devon.	Plymouth, The Hoe...	6·72	202	,, .	Bellingham, Highgreen	5·44	190
,, .	Holne, Church Pk.Cott	12·69	205	,, .	Lilburn Tower Gdns..	5·16	249
,, .	Teignmouth, Den Gdns	6·74	231	*Cumb*.	Carlisle, Scaleby Hall.	4·72	190
,, .	Cullompton	6·98	215	,, .	Borrowdale,Seathwaite	16·25	129
,, .	Sidmouth, U.D.C.....	5·98	..	,, .	Thirlmere,DaleHeadH.	14·07	169
,, .	Barnstaple,N. Dev.Ath	5·81	178	,, .	Keswick, High Hill...	8·85	175
,, .	Dartm'r,Cranmere Pool	13·30	..	,, .	Ravenglass, The Grove	4·99	149
,, .	Okehampton, Uplands.	8·78	172	*West* .	Appleby, Castle Bank.	6·19	193
Corn .	Redruth, Trewirgie...	7·48	177	*Mon* .	Abergavenny, Larchf'd	8·71	258
,, .	Penzance, MorrabGdns	8·12	214	*Glam* .	Ystalyfera, Wern Ho..	9·40	149
,, .	St. Austell, Trevarna..	8·41	197	,, .	Treherbert, Tynywaun	14·78	..
Soms .	Chewton Mendip.....	6·74	175	,, .	Cardiff, Penylan.....	6·59	179
,, .	Long Ashton	5·76	201	*Carm* .	Carmarthen,M.&P.Sch.	8·81	196
,, .	Street, Millfield	4·85	205	*Card* .	Aberystwyth	6·21	..
Glos .	Blockley	6·18	..	*Rad* .	Birm.W.W.Tyrmynydd	11·07	176
,, .	Cirencester, Gwynfa ..	5·83	232	*Mont* .	Lake Vyrnwy.....	12·19	216
Here .	Ross-on-Wye	5·67	234	*Flint* .	Sealand Aerodrome...	4·78	257
,, .	Kington, Lynhales....	5·77	205	*Mer* .	Blaenau Festiniog....	10·99	117
Salop .	Church Stretton.....	8·04	318	,, .	Dolgelley, Bontddu...	8·39	147
,, .	Shifnal, Hatton Grange	4·88	252	*Carn* .	Llandudno	5·00	207
,, .	Cheswardine Hall	5·53	250	,, .	Snowdon, L. Llydaw 9	22·50	..
Worc .	Malvern, Free Library.	5·98	271	*Ang* .	Holyhead, Salt Island.	6·04	208
,, .	Ombersley, Holt Lock.	4·87	254	,, .	Lligwy.....	7·89	..
War .	Alcester, Ragley Hall.	4·83	250	*I.Man*	Douglas, Boro' Cem...	6·19	185

Rainfall: January 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't.GrangeRd.	6·91	236	*R&C.*	Stornoway, C.G.Stn...	4·86	99
Wig .	Pt. William, Monreith.	5·18	158	*Suth .*	Lairg	3·94	120
,, .	New Luce School.....	7·50	185	,, .	Skerray Borgie.....	5·16	..
Kirk .	Dalry, Glendarroch...	5·89	106	,, .	Melvich	5·01	152
,, .	Eskdalemuir Obs.....	7·02	130	,, .	Loch More, Achfary..	7·47	103
Roxb .	Hawick, Wolfelee	6·33	198	*Caith .*	Wick	3·69	150
,, .	Kelso, Broomlands....	4·82	275	*Ork .*	Deerness	5·02	146
Peeb .	Stobo Castle.....	4·20	140	*Shet .*	Lerwick Observatory.	5·42	127
Berw .	Marchmont House....	5·81	258	*Cork .*	Cork, University Coll.	5·70	141
E.Lot.	North Berwick Res...	3·47	201	,, .	Roches Point, C.G.Stn.	4·97	120
Midl .	Edinburgh, Blackfd. H	3·25	185	,, .	Mallow, Waterloo	4·51	116
Lan .	Auchtyfardle	3·53	..	*Kerry.*	Valentia Observatory.	7·22	132
Ayr .	Kilmarnock, Kay Park	3·64	..	,, .	Gearhameen	16·90	166
,, .	Girvan, Pinmore	4·47	95	,, .	Bally McElligott Rec.	5·22	..
,, .	Glen Afton, Ayr San..	5·72	112	,, .	Darrynane Abbey....	6·82	136
Renf .	Glasgow, Queen's Park	4·71	141	*Wat .*	Waterford, Gortmore.	4·70	129
,, .	Greenock, Prospect H.	4·96	77	*Tip .*	Nenagh, Castle Lough.	4·76	120
Bute .	Rothesay, Ardencraig.	4·35	97	,, .	Cashel, Ballinamona..	3·70	99
,,	Dougarie Lodge.....	4·69	109	*Lim .*	Foynes, Coolnanes....	4·56	121
Arg .	Loch Sunart, G'dale..	4·08	58	,, .	Limerick, Mulgrave St.	4·66	122
,,	Ardgour House	6·05	..	*Clare .*	Inagh, Mount Callan..	7·08	..
,,	Glen Etive	4·45	42	*Wexf .*	Gorey, Courtown Ho..	4·81	154
,,	Oban	2·95	..	*Wick .*	Rathnew, Clonmannon	5·71	..
,,	Poltalloch	3·43	68	*Carl .*	Bagnalstown FenaghH	3·74	119
,,	Inverary Castle	5·25	64	,, .	Hacketstown Rectory.	4·61	130
,,	Islay, Eallabus	4·61	99	*Leix .*	Blandsfort House	3·74	114
,, .	Mull, Benmore.....	..	..	*Offaly.*	Birr Castle	5·03	178
,,	Tiree	2·76	65	*Kild .*	Straffan House.....	4·35	169
Kinr .	Loch Leven Sluice....	4·91	156	*Dublin*	Dublin, Phoenix Park.	3·34	147
Fife .	Leuchars Aerodrome..	4·19	230	*Meath.*	Kells, Headfort.....	5·34	170
Perth .	Loch Dhu	7·55	83	*W.M .*	Moate, Coolatore.....	4·53	..
,, .	Crieff, Strathearn Hyd.	3·53	88	,, .	Mullingar, Belvedere..	5·55	173
,, .	Blair Castle Gardens..	2·73	82	*Long .*	Castle Forbes Gdns ..	5·11	153
Angus.	Kettins School.....	3·29	126	*Gal .*	Galway, Grammar Sch.	4·18	112
,, .	Pearsie House	3·21	..	,, .	Ballynahinch Castle ..	6·90	111
,, .	Montrose, Sunnyside..	2·94	148	,, .	Ahascragh, Clonbrock.	4·60	119
Aber .	Balmoral Castle Gdns.	3·50	127	*Rosc .*	Strokestown, C'node..	4·50	144
,, .	Logie Coldstone Sch ..	3·61	163	*Mayo.*	Blacksod Point	4·44	87
,, .	Aberdeen Observatory.	3·73	171	,, .	Mallaranny.....	7·20	..
,, .	New Deer SchoolHouse	4·37	188	,, .	Westport House.....	4·30	92
Moray	Gordon Castle	3·51	174	,, .	Delphi Lodge.....	9·25	93
,, .	Grantown-on-Spey ...	7·15	295	*Sligo .*	Markree Castle.....	3·43	87
Nairn.	Nairn.....	2·77	139	*Cavan.*	Crossdoney, Kevit Cas.	5·91	..
Inv's .	Ben Alder Lodge.....	5·11	..	*Ferm .*	Crom Castle	4·79	144
,, .	Kingussie, The Birches	4·05	..	*Arm .*	Armagh Obsy.....	3·20	127
,, .	Loch Ness, Foyers....	4·46	106	*Down.*	Fofanny Reservoir ...	12·04	..
,, .	Inverness, Culduthel R	3·08	121	,, .	Seaforde	5·34	170
,, .	Loch Quoich, Loan...	6·87	..	,, .	Donaghadee, C. G. Stn.	3·96	156
,, .	Glenquoich.....	6·55	48	*Antr .*	Belfast,Queen's Univ .	4·40	154
,, .	Arisaig House	4·38	71	,, .	Aldergrove Aerodrome	3·60	131
,, .	Glenleven, Corrour ...	..	..	,, .	Ballymena, Harryville.	4·47	120
,, .	Fort William, Glasdrum	6·03	..	*Lon .*	Garvagh, Moneydig...	3·54	..
,, .	Skye, Dunvegan	4·72	..	,, .	Londonderry, Creggan.	2·78	77
,, .	Barra, Skallary	3·20	..	*Tyr .*	Omagh, Edenfel.....	3·27	92
R&C.	Tain, Ardlarach.....	3·23	114	*Don .*	Malin Head.....	3·02	92
,, .	Ullapool	3·18	69	,, .	Dunfanaghy	3·09	88
,, .	Achnashellach	5·80	60	,, .	Dunkineely.....	3·79	..

Climatological Table for the British Empire, August 1938

STATIONS.	PRESSURE.		TEMPERATURE.							Relative Humidity.	Mean Cloud Am'nt	PRECIPITATION.			BRIGHT SUNSHINE.	
			Absolute.		Mean Values.				Mean							
	Mean of Day M.S.L.	Diff. from Normal.	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from Normal.	Wet Bulb.			Am'nt.	Diff. from Normal.	Days.	Hours per day.	Percentage of possible.
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	0–10	in.	in.			
London, Kew Obsy...	1015·4	+ 0·1	84	45	71·8	55·9	63·9	+ 2·2	56·4	87	8·1	2·70	+ 0·46	12	5·1	35
Gibraltar.....	1014·2	− 2·3	83	64	78·4	66·5	72·5	− 3·5	65·7	82	3·0	0·00	—	0	—	—
Malta.....	1013·1	− 1·7	101	70	85·0	74·0	79·5	+ 0·4	71·5	70	1·9	0·15	+ 0·01	4	11·7	86
St. Helena	1019·5	− 1·6	67	53	61·4	55·4	58·4	+ 1·4	56·4	95	9·7	4·15	+ 1·66	22	—	—
Freetown, Sierra Leone	1013·1	+ 2·0	83	70	80·1	72·6	76·3	—	72·6	91	9·1	33·11	− 3·46	27	—	—
Lagos, Nigeria	1012·9	− 0·1	85	67	80·7	71·8	76·3	− 1·6	72·9	89	8·0	1·61	− 1·03	3	4·8	39
Kaduna, Nigeria	1011·5	—	87	64	80·7	67·9	74·3	+ 0·1	69·8	92	9·3	13·40	+ 1·08	25	3·1	25
Zomba, Nyasaland....	1016·4	− 0·5	82	50	75·0	54·6	64·8	− 0·1	61·3	80	2·7	0·25	− 0·12	4	—	—
Salisbury, Rhodesia ..	1017·8	− 1·3	84	34	73·3	46·5	59·9	− 0·3	49·4	44	1·9	0·00	—	0	9·5	83
Cape Town	1021·7	+ 1·4	82	37	65·5	45·6	55·5	− 0·1	47·8	80	3·3	2·78	− 0·59	11	—	—
Johannesburg	1019·6	− 0·6	76	29	65·4	42·5	53·9	− 0·5	43·5	55	1·9	0·35	− 0·16	3	8·9	79
Mauritius	1019·2	− 1·4	78	54	75·6	60·4	68·0	− 0·5	63·7	68	5·0	1·21	− 1·04	14	7·7	67
Calcutta, Alipore Obsy.	1001·4	+ 0·4	92	77	88·8	79·1	83·9	+ 0·7	79·6	89	8·4	9·64	− 3·74	17*	—	—
Bombay	1004·7	− 1·2	88	73	85·5	76·6	81·1	+ 0·3	77·1	86	8·2	16·77	+ 2·32	21*	—	—
Madras	1004·5	− 1·0	97	73	93·1	78·0	85·5	− 0·5	76·1	73	6·8	4·24	− 0·30	4*	—	—
Colombo, Ceylon	1008·9	− 0·4	85	74	84·4	76·8	80·6	− 0·6	76·7	78	8·1	4·77	+ 1·53	24	5·9	48
Singapore	1009·0	− 0·5	88	72	84·3	76·2	80·3	− 0·8	77·1	80	8·1	9·35	+ 1·40	21	4·6	38
Hongkong.....	1004·7	− 0·1	90	76	87·1	78·5	82·8	+ 0·7	78·7	82	7·5	7·89	− 6·51	19	5·1	40
Sandakan	1008·6	—	91	74	88·3	75·7	82·0	+ 0·2	77·3	83	6·8	5·73	− 2·16	12	—	—
Sydney, N.S.W.....	1019·5	+ 1·3	76	37	62·7	47·0	54·9	− 0·1	49·3	69	5·0	8·31	+ 5·34	15	5·9	54
Melbourne	1020·4	+ 2·4	71	29	59·2	42·2	50·7	− 0·3	45·9	75	6·7	0·99	− 0·88	17	4·4	42
Adelaide	1021·0	+ 1·8	70	36	61·5	44·9	53·2	− 0·8	48·8	72	6·3	2·69	+ 0·15	16	5·3	49
Perth, W.Australia....	1022·7	+ 3·8	76	41	64·6	49·7	57·1	+ 1·1	51·5	70	6·7	5·51	− 0·14	18	5·9	54
Coolgardie	1021·8	+ 2·5	77	35	64·1	42·6	53·3	− 0·3	47·3	63	3·6	0·57	− 0·42	5	—	—
Brisbane.....	1020·7	+ 1·5	80	41	68·7	49·8	59·3	− 1·1	52·0	69	3·6	1·21	− 0·80	6	7·4	66
Hobart, Tasmania....	1017·0	+ 3·6	66	33	55·2	41·6	48·4	+ 0·4	44·0	73	5·0	1·11	− 0·72	16	4·9	47
Wellington, N.Z.....	1018·6	+ 3·5	61	33	53·0	42·5	47·7	− 0·9	45·3	79	7·5	7·00	− 2·51	13	4·9	47
Suva, Fiji	1014·9	+ 0·7	88	66	80·9	71·2	76·1	+ 2·5	71·7	85	6·8	7·05	− 1·24	21	3·9	34
Apia, Samoa	1012·2	− 0·1	86	71	84·4	74·2	79·3	+ 1·5	75·3	79	6·1	5·26	+ 1·63	23	8·2	70
Kingston, Jamaica ...	1012·8	− 0·7	93	72	89·0	74·1	81·5	0·0	72·8	80	3·8	6·23	+ 2·68	10	8·6	68
Grenada, W.I.	1010·6	− 2·0	89	70	87	73	80·0	+ 0·3	73	74	6	13·60	+ 4·27	27	—	—
Toronto.....	1014·9	− 0·5	92	53	82·7	63·1	72·9	+ 5·7	64·5	82	3·6	2·06	− 0·73	8	8·9	64
Winnipeg	1012·0	− 1·2	92	41	80·1	54·2	67·1	+ 3·3	54·4	83	4·4	1·74	− 0·42	10	9·3	64
St. John, N.B.	1013·9	− 1·4	84	47	71·9	56·9	64·4	+ 3·8	59·9	86	6·6	3·95	+ 0·09	15	7·4	52
Victoria, B.C.....	1018·2	+ 1·3	78	48	66·7	51·1	58·9	− 0·8	54·5	81	3·3	0·55	− 0·09	5	10·3	72

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

(45883) Wt. 20/31 1,250 2/39 Hw. G.377/6